ISSN 1819-1878

# Asian Journal of Animal Sciences

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OPEN ACCESS Asian Journal of Animal Sciences

ISSN 1819-1878
DOI: 10.3923/ajas.2020.153.160

# Research Article

# Performance, Carcass Traits and Blood Parameters of Broiler Chickens Fed Roasted and Boiled Bambara Groundnut (*Vigna subterranea* (L.) *Verdc.*)

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## Abstract

**Background and Objective:** The competition between human and livestock in the traditional protein sources such as soybean and groundnut makes an urgent need to find out cheap and nutritive non-conventional sources. The study aimed to investigate the effect of dietary incorporation of differently processed Bambara groundnut with roasting (A) and boiling (B) on broiler performance, carcass traits and blood parameters. **Materials and Methods:** The roasted and boiled Bambara groundnuts were ground and analyzed to be included in the experimental diets. The inclusion levels (treatments) of roasted Bambara groundnut were 10% ($A_1$), 15% ($A_2$) and 20% ($A_3$) and for boiled one were 10% ($B_1$), 15% ($B_2$) and 20% ($B_3$). The control diet contained 0% Bambara groundnut (C). A total of 350 one-day-old Hubbard broilers were allocated to the seven treatments and each treatment was divided randomly into five replicates with ten birds each. **Results:** The results showed that the tannin and phytate content of Bambara groundnut were reduced by roasting and boiling treatments. Feed consumption, weight gain and feed conversion ratio were not affected by treatments. The weights of live body and carcass of birds fed on diets containing Bambara groundnut were greater than birds fed on the control diet. The relative weights of proventriculus, gizzard, pancreas, spleen and abdominal fat were not influenced by experimental treatments. Moreover, differential leucocytes counts were not influenced by experimental treatments. **Conclusion:** The results indicate that, processed Bambara groundnut could be used as a source of protein up to 20% in broiler diets without adverse effects.

Key words: Bambara groundnut, boiling, roasting, anti-nutritional factors, broilers

Citation: Mahmoud, M.S.B., A.G.F Mohamad and A.A. Abaker, 2020. Performance, carcass traits and blood parameters of broiler chickens fed roasted and boiled bambara groundnut (*Vigna subterranea* (L.) *Verdc.*). Asian J. Anim. Sci., 14: 153-160.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Soybean and peanut meals are the conventional sources of protein in poultry diets because of their higher contents of essential amino acids. The availability and prices of soybean and groundnut are correlated with international trade policies and world market demand. Moreover, the competition between humans and livestock in soybean and groundnut makes an urgent need to find out cheap and nutritive non-conventional protein sources. Legumes are considered one of the plant classes that could be exploited to be the alternative protein source in poultry diets. Legumes are rich in protein and other nutrients needed for good growth performance. However, the nutritive value of legumes depends on their anti-nutritional content which inhibits nutritional utilization when consumed without processing[1].These antinutritional factors decrease the nutritive values of legumes directly or indirectly through impairment of the digestibility of protein and other nutrients and alteration in the tissues of the intestine and liver[2]. One of those legumes that could be exploited as a feedstuff is Bambara groundnut (*Vigna subterranea* (L.) *Verdc.*). It is found in tropical and subtropical areas and is characterized by tolerance to harsh climatic conditions[3]. Bambara groundnut seed is composed of 65% carbohydrate and 18% crude protein[4-5]. The crop supplied sub-Saharan African with protein where the people are not able to purchase animal origin protein[6]. Bambara groundnut has higher percentages of lysine and methionine when compared with cowpea and chickpea[7]. The methionine content of the Bambara groundnut is greater than that of soybean by three times[8]. Bambara groundnut is included in poultry diets as a source of protein to supply the amino acids required for growth and meat production[9]. The dietary inclusion of raw Bambara groundnut in monogastric diets is limited and that is due to its antinutritional factors such as trypsin inhibitor, tannin, phytic acid and high fiber content[10]. These compounds have deleterious effects on the performance of poultry. To incorporate Bambara groundnut as a source of protein in broiler diets, the antinutritional factors need to be treated physically or chemically. Heat processing is one of the technical methods used in order to decrease these antinutritional factors and to improve nutrients availability. Therefore, the current study was designed to evaluate the effect of feeding varying dietary levels of Bambara groundnut subjected to boiling and roasting processing on growth performance and carcass characteristics of broiler chickens.

## MATERIALS AND METHODS

**Study area:** This experiment was carried out at Extension and Rural Development Centre (E.R.D.C.), Faculty of Animal Production, University of Gezira, Sudan. The mean values of minimum and maximum temperature during hot months were 47°C and 28°C and of the rainy months were 32°C and 20°C, respectively. The relative humidity was 45 and 80% in the hot dry months and the hot rainy ones, respectively. The experimental duration was extended from 22th May 2018 to 10th July 2018.

**Collection and preparation of Bambara groundnut:** Bambara groundnut was purchased from the crop market in Khartoum (Central Sudan). Bambara groundnut used in the experiment were dehulled, cleaned and divided into two groups. The first group (A) was treated by roasting and the second one (B) was subjected to boiling treatment. Bambara groundnut seeds of (A) group were roasted by manual turning in gas fire using special locally designed drum for 45 min. The second group (B) of Bambara groundnut seeds was put in boiled tap water (100°C) for 15 min. Then, the water was drained and the boiled seeds were air dried for five days. Thereafter, the raw, roasted and boiled Bambara groundnut seeds were subjected to grinding, proximate analysis[11] and assessment of tannin and phytic acid (Table 1). Both of roasted and boiled Bambara groundnut seeds were incorporated in the experimental diets at three levels (10%, 15% and 20%).

**Experimental birds, design and management:** A total of 350 one-day old broiler chicks (Hubbard classic) were brought from a commercial hatchery. The birds were kept in open-sided house with deep litter system throughout the experimental period. The house was divided into 35 pens. The dimensions of each pen were (100 cm) length, (100 cm) width and (90 cm) height. The experimental period was divided into starter (0-3 week of age) and finisher (4-7 week of age). Two

Table 1: Chemical composition of raw, roasted and boiled Bambara groundnut

| Item | Treatments<br>Raw | Roasted | Boiled |
|---|---|---|---|
| Crude protein (%) | 17.70 | 13.10 | 12.50 |
| Crude fiber (%) | 13.20 | 12.20 | 10.70 |
| Ether extract (%) | 7.30 | 7.80 | 6.60 |
| Nitrogen free extract (%) | 52.50 | 58.40 | 57.30 |
| Ash (%) | 3.90 | 3.90 | 3.50 |
| Metabolizable energy (kcal/kg)* | 2823.5 | 2906.7 | 2867.8 |
| Tannin (%) | 0.78 | 0.71 | 0.65 |
| Phytic acid (%) | 1.05 | 0.78 | 0.83 |

*Metabolizable energy was calculated according to the equation of Lodhi *et al.*[13]

heat processing of Bambara groundnut (roasted A) and (boiled B) were allocated in three levels of dietary inclusion: 10% ($A_1$), 15% ($A_2$) and 20% ($A_3$) and 10% ($B_1$), 15% ($B_2$) and 20% ($B_3$), respectively. The treatment without Bambara groundnut was considered as control (C). The experimental design used was completely randomized design. Each treatment was replicated five times with ten birds each. The experimental diets were formulated to meet or exceed the requirements of the boilers[12]. Table 2 and 3 showed the composition of the diet of starter and finisher periods. The birds had free access for feed and water throughout the experimental period (*adlibitum*).

Table 2: The composition of experimental diets (% as fed) during the starter period (0-3 weeks of age)

| | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| | Roasted bambara nut (A) | | | Boiled bambara nut | | | |
| Ingredients | $A_1$ (10%) | $A_2$ (15%) | $A_3$ (20%) | $B_1$ (10%) | $B_2$ (15%) | $B_3$ (20%) | Control C (0%) |
| Sorghum | 55 | 51.2 | 47.63 | 55 | 51.22 | 49 | 56 |
| Groundnut cakes | 20 | 20.17 | 20.2 | 19.2 | 20.15 | 18.21 | 20.5 |
| Wheat bran | 7.63 | 5.5 | 4.5 | 8.23 | 5.4 | 4.58 | 13.9 |
| Bambara nut | 10 | 15 | 20 | 10 | 15 | 20 | 0 |
| Concentrate | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Di-calcium phosphate | 0.12 | 0.4 | 0.2 | 0.12 | 0.4 | 0.04 | 1.02 |
| limestone | 0.07 | 0.05 | 0.04 | 0.08 | 0.05 | 0.03 | 0.2 |
| Sodium chloride | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Lysine | 0.04 | 0.05 | 0.04 | 0.03 | 0.05 | 0.5 | 0.4 |
| DL-Methionine | 0.03 | 0.03 | 0.05 | 0.03 | 0.03 | 0.03 | 0.05 |
| Vegetable-oil | 1.3 | 1.7 | 1.53 | 1.5 | 1.8 | 1.8 | 2.12 |
| Premix[1] | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Anti-toxin | 0.01 | 0.1 | 0.01 | 0.01 | 0.1 | 0.01 | 0.01 |
| **Calculated analysis** | | | | | | | |
| ME (kcal/kg)[2] | 3208 | 3203 | 3202 | 3208 | 3204 | 3202 | 3237 |
| Protein (%) | 23 | 23 | 23 | 23 | 23 | 23 | 23 |

[1]Vitamin: Mineral premix provided the following per kilogram of diet: Vitamin (retinyl acetate), 10.000IU; Cholecalciferol, 2.500IU;" Tocopheryl acetate, 60 mg; Menadione sodium bisulfide complex, 15mg; Thiamine hydrochloride, 2 mg; Riboflavin, 8 gram pyridoxine hydrochloride, 4 mg; Cyanocobalamin., 04 mg; Pantothenic acid 15 mg; Nicotinic acid, 40 mg; Folic acid, 1.5 mg; Biotin, 2 mg; Choline chloride, 200 mg; Iron, 50 mg; Manganese, 50 mg; Copper, 10 mg; Zinc, 50 mg; Calcium 352 mg; Iodine, 1.46 mg; Cobalt. 5 mg; Selenium, [2]Values and metabolizable energy were calculated according to Lodhi *et al.*[13]

Table 3: The composition of experimental diets (% as fed) during the finisher period (4-7 weeks of age)

| | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| | Roasted Bambara nut (A) | | | Boiled Bambara nut | | | |
| Ingredients | $A_1$ (10%) | $A_2$ (15%) | $A_3$ (20%) | $B_1$ (10%) | $B_2$ (15%) | $B_3$ (20%) | Control C (0%) |
| Sorghum | 55 | 49 | 50 | 50 | 53 | 48 | 60.01 |
| Ground nut cakes | 10.8 | 11.21 | 12 | 11 | 10.8 | 12 | 10.51 |
| Wheat bran | 16.4 | 16.55 | 10 | 20 | 13 | 11.2 | 20.01 |
| Bambara nut | 10 | 15 | 20 | 10 | 15 | 20 | 0 |
| Concentrate | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Di-calcium phosphate | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.3 | 1.01 |
| limestone | 0.3 | 0.24 | 0.4 | 0.3 | 0.32 | 0.3 | 0.5 |
| Sodium chloride | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Lysine | 0.12 | 0.17 | 0.12 | 0.35 | 0.05 | 0.35 | 0.13 |
| DL-Methionine | 0.02 | 0.03 | 0.02 | 0.05 | 0.03 | 0.05 | 0.03 |
| Vegetable-oil | 1.26 | 1.7 | 1.36 | 2.1 | 1.5 | 1.9 | 1.9 |
| Premix[1] | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Anti-toxin | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Calculated analysis** | | | | | | | |
| ME (kcal/kg)[2] | 3200 | 3200 | 3200 | 3208 | 3200 | 3201 | 3200 |
| Protein (%) | 20 | 20 | 20 | 23 | 20 | 20 | 20 |

[1]Vitamin: Mineral premix provided the following per kilogram of diet: Vitamin (retinyl acetate), 10.000IU; Cholecalciferol, 2.500IU;" Tocopheryl acetate, 60 mg; Menadione sodium bisulfide complex, 15mg; Thiamine hydrochloride, 2 mg; Riboflavin, 8 gram pyridoxine hydrochloride, 4 mg; Cyanocobalamin., 04 mg; Pantothenic acid 15 mg; Nicotinic acid, 40 mg; Folic acid, 1.5 mg; Biotin, 2 mg; Choline chloride, 200 mg; Iron, 50 mg; Manganese, 50 mg; Copper, 10 mg; Zinc, 50 mg; Calcium 352 mg; Iodine, 1.46 mg; Cobalt. 5 mg; Selenium, [2]Values and metabolizable energy were calculated according to Lodhi *et al.*[13]

**Experimental measurements:** During the entire experimental period, the values of bodyweight gain (BWG) and Feed Consumption (FC) of broilers were recorded and hence the Feed Conversion Ratio (FCR) calculated.

At the end of the experimental period, two birds from each experimental unit (replicate) were selected based on their closed weight to the birds' average weight in the particular pen for collection of blood samples and slaughter performance. The blood samples were collected for the determination of metabolites and hematological profile. For assessment of slaughter performance, carcass weight and relative weights of liver, spleen, kidney, gizzard, proventriculus, pancreas, abdominal fat and the length of intestine were recorded. Moreover, the relative weights of breast, thigh and drumstick were measured.

**Chemical analysis**

**Chemical composition of Bambara groundnut:** Raw and processed Bambara groundnut were subjected to proximate analysis[13]. The method of Wheeler and Ferrel[14] was used for the determination of phytic acid using 2.0 g of sample. A standard curve was prepared expressing the results as Fe $(No_3)_3$equivalents. Phytate phosphorus values were calculated from the standard curve assuming a 4:6 iron to phosphorus molar ratio. For determination of tannin, hundred milligrams of the dried sample was weighed, then they were dissolved in 10 mL 70% acetone and kept in an ultrasonic water bath for 35 min, then the mixture was centrifuged at 4°C, 3000 rpm for 10 min. The supernatant was taking as an Original Extract (OE) and kept in the refrigerator. The condensed tannin was assessed using the Butanol method[15]. Three replications of test tubes 100×10 mm were used for each sample, 250 mL of (OE), 1500 mL of Butanol-HCl reagent, 50 mL of Ferric reagent, tubes were covered with glass marbles and two replicates of each sample were heated in water bath at 97-100°C, one (unheated) replicate was used as blank. The absorbance was read using a spectrophotometer (BioSystems S. A. Costa Brava 30, Barcelona, Spain) at 550 nm against blank for each sample. Condensed tannin (% dry matter) was determined using the leucocyanidin equivalent formula:

$$CT = (A \times 78.26 \times F)/(DM\%)$$

where, A is Absorption at 550 nm, F is Dilution factor (if the sample absorption was greater than 600 it would be diluted.), DM is dry matter and CT is Condensed tannin in dry matter.

**Blood biochemical and hematological measurements:** Blood samples were collected from the wing -vein using 0-5 mL syringe and drawn into test tube containing an anticoagulant in order to determined cholesterol[16], tri-glyceride[16], total protein[17], albumin, globulin and glucose. Then, they were determined spectrophotometrically by using commercial kits. To determine the number of White Blood Cell (WBC's) and different types of leukocytes. WBCs were counted using magnification count on an Ao bright line hemocytometer using a light microscope at 400× and 100×, respectively[18].

**Statistical analysis:** Data were statistically analyzed as a completely randomized design by Analysis of Variance (ANOVA) using the SPSS (SPSS 20.0 for windows, SPSS Inc., Chicago, IL). Differences between mean values of the treatments were determined using Duncan's multiple-range test[19].

## RESULTS

The chemical composition of raw and processed Bambara groundnut are presented in Table 1. One of the important observations is that the heat treatments reduced protein content of processed Bambara groundnut. In similar pattern, Bambara groundnut tannin and phytic acid content were reduced when subjected to roasting and boiling processing. Table 4 shows the effects of dietary inclusion of different levels of roasted and boiled Bambara groundnut used during the starter, finisher and entire experimental periods on broiler performance. During the starter period, average weight gain, feed consumption and feed conversion ratio were affected significantly ($p \leq 0.05$) by different treatments. The largest amounts of feed were consumed by birds fed with diet containing roasted Bambara groundnut. Numerically, the greatest weight gain values were reported with birds fed on $A_2$, $A_3$ and $B_2$ diets. The best Feed Conversion Ratio (FCR) was reported with the birds fed with $B_2$ diet while the worst one was observed with the birds fed on $A_1$ diet. During the finisher and entire experimental periods, no significant effects have been reported of the dietary treatments on feed consumption, weight gain and FCR.

As shown in Table 5 the relative weight values of internal organs were not affected by different experimental treatments except the length of intestine, which was influenced by the inclusion of different processed Bambara groundnut. All birds fed on diets with Bambara groundnut had longer intestine than that of those birds fed on control diets. The only exception was reported with $A_2$ treatment, which had no significant difference when compared with control treatment. Table 6 shows that carcass weight and relative weight of breasts were affected significantly ($p \leq 0.01$) by experimental treatments. Whereas, no noticeable effects of treatments on relative weights of thigh and drumstick. The heaviest carcasses were reported with Bambara groundnut treatments. The largest relative weights of breasts were observed with $A_2$ and $B_1$ treatments, while the lowest ones were recorded with $A_3$, $B_2$ and $B_3$ treatments.

Table 7 showed that the blood total protein, cholesterol and triglyceride were affected significantly ($p \leq 0.01$) by the experimental treatments. The highest total blood protein was reported with birds fed on $A_1$ diets whereas the birds fed with $B_1$ showed the lowest values. The highest blood Cholesterol was observed with birds fed on $B_3$ diet. While no difference was observed between control and all Bambara groundnut treatments. Experimental treatments had no significant impact on blood glucose. The hematological parameters were not influenced by experimental treatments, except for red

Table 4: Effect of incorporating dietary processed Bambara groundnut on broiler performance during the starter, finisher and entire experimental feeding phases

| | Treatments | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Roasted bambara groundnut | | | Boiled bambara groundnut | | | | | |
| Trait | $A_1$ (10%) | $A_2$ (15%) | $A_3$ (20%) | $B_1$ (10%) | $B_2$ (15%) | $B_3$ (20%) | Control (0%) | SEM | Significance |
| **Starter period (weeks 0-3)** | | | | | | | | | |
| Feed consumption (g) | 368.26$^a$ | 361.28$^a$ | 360.68$^a$ | 340.03$^b$ | 330.75$^c$ | 330.84$^c$ | 339.39$^b$ | 7.9 | * |
| Average Weight gain (g) | 241.86$^{bc}$ | 262.93$^a$ | 250.8$^{ab}$ | 237.3$^{cd}$ | 256.93$^{ab}$ | 224.09$^d$ | 223.01$^d$ | 8.2 | * |
| Feed conversion (g:g) | 1.5$^c$ | 1.37$^b$ | 1.45$^{bc}$ | 1.44$^b$ | 1.28$^a$ | 1.48$^{bc}$ | 1.49$^{bc}$ | 0.1 | * |
| **Finisher period (weeks 4-7)** | | | | | | | | | |
| Feed consumption (g) | 664.26 | 693.44 | 712.07 | 701.71 | 664.86 | 712.52 | 690.57 | 15.5 | NS |
| Average weight gain (g) | 339.06 | 300.30 | 321.66 | 310.42 | 303.12 | 337.12 | 275.52 | 19.9 | NS |
| Feed conversion (g:g) | 2.06 | 2.58 | 2.40 | 2.33 | 2.25 | 2.17 | 2.52 | 0.19 | NS |
| **Entire experimental period (weeks 0-7)** | | | | | | | | | |
| Feed consumption (g) | 510.52 | 524.74 | 534.39 | 521.37 | 497.8 | 521.68 | 514.96 | 8.3 | NS |
| Average weight gain (g) | 288.66 | 281.76 | 288.89 | 280.61 | 256.77 | 281.76 | 256.77 | 10.8 | NS |
| Feed conversion (g:g) | 1.8 | 1.99 | 1.87 | 1.91 | 1.79 | 1.82 | 2.01 | 0.1 | NS |

$^{a-d}$Mean values within a row not sharing the same superscripts are significantly different ($p<0.05$), NS: Not significant, SEM: Pooled standard error of means

Table 5: Effect of dietary incorporation of processed Bambara groundnut on broiler relative weights of internal organs (% of body weight) and the length of the intestine

| | Treatments | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Roasted Bambara groundnut | | | Boiled Bambara groundnut | | | | | |
| Parameters | $A_1$ (10%) | $A_2$ (15%) | $A_3$ (20%) | $B_1$ (10%) | $B_2$ (15%) | $B_3$ (20%) | Control (0%) | SEM | Significance |
| Liver weight (%) | 2.44 | 2.1 | 2.49 | 2.58 | 2.12 | 2.51 | 2.22 | 0.23 | NS |
| Gizzard weight (%) | 3.36 | 2.57 | 3.13 | 2.99 | 2.90 | 3.12 | 2.92 | 0.24 | NS |
| Proventriculus weight (%) | 0.53 | 1.51 | 1.48 | 0.51 | 0.44 | 0.57 | 0.55 | 0.62 | NS |
| Spleen weight (%) | 0.06 | 0.07 | 0.07 | 0.08 | 0.06 | 0.08 | 0.07 | 0.01 | NS |
| Pancreas weight (%) | 0.19 | 0.15 | 0.20 | 0.19 | 0.18 | 0.19 | 0.20 | 0.02 | NS |
| Abdominal fat weight (%) | 2.33 | 1.75 | 1.97 | 1.73 | 1.63 | 1.90 | 1.86 | 0.24 | NS |
| Kidney weight (%) | 0.58 | 0.59 | 0.63 | 0.65 | 0.58 | 0.61 | 0.69 | 0.04 | NS |
| Length of small intestine (cm) | 141.67$^a$ | 131.33$^{ab}$ | 155.33$^a$ | 144.17$^a$ | 153.5$^a$ | 149.17$^a$ | 113.23$^b$ | 9.31 | * |

$^{a,b}$Mean values within a row not sharing the same superscripts are significantly different ($p<0.05$), NS: Not significant, SEM: Pooled standard error of means

Table 6: Effect of dietary incorporation of processed Bambara groundnut on broiler carcass and cut-up parts

| | Treatments | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Roasted bambara groundnut | | | Boiled bambara groundnut | | | | | |
| Parameters | $A_1$ (10%) | $A_2$ (15%) | $A_3$ (20%) | $B_1$ (10%) | $B_2$ (15%) | $B_3$ (20%) | Control (0%) | SEM | Significance |
| Carcass weight (g) | 1032.83$^A$ | 1083.67$^A$ | 1079.33$^A$ | 1039.33$^A$ | 1072.33$^A$ | 1011$^A$ | 855$^B$ | 38.46 | ** |
| Breast weight (%) | 10.53$^{BC}$ | 10.97$^{AB}$ | 9.95$^C$ | 11.7$^A$ | 9.71$^C$ | 9.97$^C$ | 10.41$^{BC}$ | 0.30 | ** |
| Thigh weight (%) | 5.11 | 5.64 | 5.77 | 5.74 | 5.95 | 5.32 | 5.56 | 0.23 | NS |
| Drumstick weight (%) | 5.31 | 5.47 | 5.45 | 5.39 | 5.48 | 4.97 | 5.29 | 0.18 | NS |

$^{A-C}$Mean values within a row not sharing the same superscripts are significantly different ($p \leq 0.01$), NS: Not significant, SEM: Pooled standard error of means

Table 7: Effect of dietary incorporation of processed Bambara groundnut on some hematological and serum parameters

| | Treatments | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Roasted bambara groundnut | | | Boiled bambara groundnut | | | | | |
| Parameters | $A_1$ (10%) | $A_2$ (15%) | $A_3$ (20%) | $B_1$ (10%) | $B_2$ (15%) | $B_3$ (20%) | Control (0%) | SEM | Significance |
| Total protein (g $dL^{-1}$) | $2.82^{A}$ | $2.68^{BC}$ | $2.64^{BC}$ | $2.41^{D}$ | $2.68^{BC}$ | $2.81^{A}$ | $2.56^{C}$ | 0.07 | ** |
| Glucose (g $dL^{-1}$) | 150 | 161.33 | 167.67 | 171.67 | 177.67 | 152 | 172.33 | 15.05 | NS |
| Cholesterol (g $dL^{-1}$) | $67.93^{BC}$ | $69.2^{BC}$ | $61.65^{C}$ | $76.8^{B}$ | $70.5^{BC}$ | $97.9^{A}$ | $72.82^{BC}$ | 4.43 | ** |
| Triglyceride (g $dL^{-1}$) | $74.05^{A}$ | $42.95^{CD}$ | $36.3^{D}$ | $46.30^{C}$ | $68.3^{A}$ | $40.53^{CD}$ | $57^{B}$ | 3.03 | ** |
| Red blood cells ($\times 10^6$ μL) | $1.81^{AB}$ | $1.98^{A}$ | $1.46^{C}$ | $1.47^{C}$ | $1.38^{C}$ | $1.58^{BC}$ | $2.05^{A}$ | 0.08 | ** |
| Hemoglobin (Hb) (g $dL^{-1}$) | 9.22 | 9.58 | 8.9 | 8.67 | 8.48 | 8.88 | 9.07 | 0.25 | NS |
| White blood cells ($\times 10^3$ μL) | $35.1^{C}$ | $63.97^{A}$ | $63.7^{A}$ | $60.7^{A}$ | $58.28^{A}$ | $58.07^{A}$ | $49.33^{B}$ | 2.39 | ** |
| Heterophils /Lymphocyte | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.00 | NS |
| Basophil (B) | 0.33 | 0.01 | 0.67 | 0.33 | 0.33 | 0.67 | 0.67 | 0.31 | NS |
| Eosinophil (E) | 0.67 | 0.67 | 0.67 | 0.67 | 0.01 | 0.67 | 1.00 | 0.28 | NS |

$^{A-D}$Mean values within a row not sharing the same superscripts are significantly different ($p \leq 0.01$), NS: Not significant, SEM: Pooled standard error of means

(RBC) and White Blood Cells (RBC). All birds fed on diets containing Bambara groundnut had greater values of white blood cells than those birds fed on control diets. The only exception was reported with $A_1$ treatment, which scored lower value of WBC when compared with control.

## DISCUSSION

The current study revealed that protein content was reduced when Bambara groundnut was subjected to heat treatments. The reduction of protein content by boiling processing may be due to leaching and vaporization of some nitrogenous compounds during processing Uche, *et al.*[20]. Also, he reported that tannin and phytate of Bambara groundnut were reduced by boiling and roasting[20]. Ene-Obong and Obizoba[21] reported that two-third of phytic acid could be reduced by boiling processing. Similar findings have been recorded in the current study. This study indicated that during the starter period, feed consumption values were greater for the birds fed on diets containing roasted Bambara groundnut than other treatments. These results may be due to the enhancement of palatability due to roasting processing which were in agreement of Kordylas[22] who reported that toasting (roasting) is reputed to add better and attractive flavor to food. The birds fed on diets contained roasted Bambara groundnut gained greater weights than those fed on control diets. During the finisher and entire experimental periods, no noticeable differences in performance parameters were observed between different treatments. These results were in disagreement with Oloyede *et al.*[1] who reported that dietary inclusion of roasted Bambara groundnut impaired the broiler performance when compared with those fed on control and diets containing fermented Bambara groundnut. This contradiction of results may be due to the differences in the duration of roasting applied. Eventually, suppression of nutrients availability will take place resulting from a long time of roasting processing[23]. Overheating reduced the protein digestibility either by reduction of the availability of amino acids or by denaturation of protein[24]. These results indicated that the adopted heat treatments in the present study were quite sufficient to inactivate the antinutritional factors. On the other hand, the amino acids were kept in adequate manner to be utilized.

The present results indicated that the relative weights of internal organs were not influenced ($p \geq 0.05$) by different experimental treatments except the length of intestine. These results may be due to inactivated antinutritional factors by experimental heat treatments which did not any alteration in internal organs. All birds fed on diets with Bambara groundnut had longer intestine than that of those birds fed on control diets. Birds fed with $A_2$ diets had similar intestinal length when compared with those of control treatment. This increased in length probably related to the high crude fiber content in Bambara groundnut. Jorgensen *et al.*[25] reported that non-starch polysaccharides (NSPs) could increase the gastrointestinal tract. So, the higher levels of fiber might be responsible for hypertrophy of the intestinal tract[26,27]. The carcass weights of the birds fed on diets contained processed Bambara groundnut were greater than those fed on control diets. Numerically the weight gain values and FCR of birds fed on diets contained Bambara groundnut were better than control. Consequently, the weights of the carcass of Bambara groundnut treatments were greater than those of control. From nutritional stand point, these results indicated that the treated Bambara groundnut with peanut meal are integrated in such way that making good synthesis of tissues. The relative weights of thigh and drumstick were similar among all experimental birds. The findings of the present study were not fully consistent with Nwambe *et al.*[28] who reported that the relative weights of thigh, drumstick and breast were significantly different among experimental treatments. These discrepancies may be due to the differences in experimental treatments and the percentages of the adopted processed Bambara groundnut.

White blood cells of the birds fed on diets with Bambara groundnut were greater than control treatment. This may be an indication of the immune system response to antigenic protein or antinutritional factor attempting to alleviate their negative impact[29]. But, single immunity index could not be considered as an indicator of immunity enhancement[30]. Moreover, no differences were observed among treatments for basophils, eosinophils and heterophils/lymphocytes. Numerically, as the level of roasted or boiled Bambara groundnut increased over the lowest level (10%), the triglyceride decreased and that is may be attributed to the higher dietary fiber content, which is known to reduce dietary fat utilization. These results agreed with Lairon[31] who reported that, the presence of non-starch polysaccharides in the diets could affect the digestibility, absorption and metabolism of lipids and cholesterol.

## CONCLUSION

The study revealed that heat processing (boiling and roasting) reduced tannin and phytate content of Bambara groundnut which increased the bioavailability of nutrients in broiler diets. During the entire experimental period roasted (A) and boiled (B) treatments were better than control (C) in most tested parameters. All birds fed on a diet containing processed Bambara groundnut (A and B) had greater carcass weights than those fed with control diets. The results indicate that, processed Bambara groundnut could be used as a source of protein up to 20% in broiler diets without adverse effects.

## SIGNIFICANCE STATEMENT

The current study proofs the effects of processed Bambara groundnut as a non-conventional protein source on the performance of broiler chickens. The findings of the study will help researchers to exploit the Bambara groundnut without negative impacts using differently heat processing. The study will contribute significantly in reduction of poultry production cost due to the high cost of the conventional protein sources.

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